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Helminth Parasites From the Stomach of Conger Eel, *Conger conger*, From Madeira Island, Atlantic Ocean

Graça Costa, Maria J. Santos*, Luísa Costa†, Manuel Biscoito†, Miguel A. A. Pinheiro de Carvalho, and Egberto Melo-Moreira, CEM, Universidade da Madeira, Campus da Penteada 9000-390 Funchal, Portugal; *CIMAR/CIIMAR—Centro Interdisciplinar de Investigação Marinha e Ambiental and Departamento Zoologia e Antropologia, Faculdade de Ciências, Universidade do Porto, Pç Gomes Teixeira 4050-290 Porto, Portugal; †EBMF/MMF—Estação de Biologia Marinha do Funchal/Museu Municipal do Funchal (História Natural), Promenade Orla Marítima do Funchal, 9000-107 Funchal, Portugal. *e-mail: gcosta@uma.pt*

ABSTRACT: Geographic variations in the diversity and prevalence of helminth parasites of fish can provide important clues as to the relatedness of fish populations. In the present work, the stomachs of 64 conger eels, *Conger conger*, collected during 1999 and 2000, were examined for the presence of parasites. Four fish were infected with L3 stages of the nematode *Anisakis simplex* s.l. (Anisakidae), 1 with the nematode *Cristitectus congeri* (Cystidicolidae), 1 with the acanthocephalan *Rhadinorhynchus pristis*, 17 with postlarvae of *Sphyriocephalus tergestinus* (Eucestoda: Trypanorhyncha), and 55 with *Lecithochirium* spp. (Digenea: Hemiuridae). The hemiurids were the most abundant parasites, with a total of 385 individuals recovered. Strong aggregated distributions were found for both the digeneans, *Lecithochirium musculus* and *Lecithochirium fusiforme*, with variance-to-mean ratios (s^2/x) and index of discrepancy (D) 13.98 and 0.672 (for *L. musculus*) and 8.08 and 0.90 for *L. fusiforme*, respectively. Intensity of *L. musculus*, *L. fusiforme*, and *S. tergestinus* showed significant relationships with depth of capture. Differences in number of species and prevalence were found between Madeira and the Atlantic coasts of the Iberian Peninsula.

Conger conger Linnaeus 1758 (Teleostei: Anguilliformes) is a benthic marine species, with a geographical distribution extending through the northeastern Atlantic, the Mediterranean, and the Black Sea (Bauchot and Saldanha, 1986). This fish species has a relative commercial importance in Madeira, with catches accounting for 0.20% of total fish catches (data not shown).

Although several helminth parasites have been reported from the digestive tract (stomach and intestine) of this fish species from the Iberian Peninsula, i.e., Spain and Portugal (SanMartin et al., 2000; Saraiva et al., 2000) and the Mediterranean (Gibson and Bray, 1986; Bartoli and Gibson, 2007), its parasite composition remains almost unknown in Madeiran waters. Parasites can be used as indicators of environment quality and host biology, including migratory behavior and feeding ecology, as well as in defining population units (Williams et al., 1992; MacKenzie et al., 1995; MacKenzie, 2002).

The present work is a study of the helminth parasites found in the stomach of conger eel from Madeiran waters. The aim was to identify helminth species present and compare their diversity and prevalence with the Iberian coastal region of the Atlantic where the fish host is a common inhabitant.

Sixty-four conger eels, *Conger conger*, ranging in length from 44.4 to 178.9 cm (114 ± 25.76, mean ± SD) and weight from 116.2 to 14,500 g (3,584.6 ± 2,561.9), were caught in Madeiran waters, in the northeastern Atlantic Ocean (33°7′30″, 32°22′20″N and 16°16′30″, 17°16′38″W) during 1999–2000, at depths between 200 and 700 m. Fish were frozen immediately after capture and brought to the laboratory. After the fish were thawed, stomachs were removed and the contents preserved in 70% ethanol. Helminths were later recovered from the preserved stomach contents and separated according to taxonomic group. Nematodes and cestodes were cleared in lactophenol and mounted as temporary preparations in glycerol jelly. They were identified according to Berland (2005) and Palm (2004). Digeneans were stained in acetic carmine, cleared in beechwood creosote, mounted in Canada balsam or Entellan, and identified according to Gibson and Bray (1986). All helminths were studied and identified by light microscopy.

Parasitological parameters (prevalence, intensity, and abundance) were calculated according to Bush et al. (1997). Aggregation was quantified with the variance-to-mean ratios (s^2/x) and index of discrepancy (D) of Poulin (1993), with the program Quantitative Parasitology by Rozsá et al. (2000). The Pearson correlation coefficient was used to test the relationship between intensity of helminths and depth of capture (Fowler et al., 2001). The relationship between host length and abundance of helminths was examined with the use of the Spearman correlation coefficient.

A single individual of *Cristitectus congeri* (Nematoda: Cystidicolidae), 5 specimens of L3 larvae of *Anisakis simplex* s.l. (Anisakidae), 48 postlarvae of *Sphyriocephalus tergestinus* (Eucestoda: Trypanorhyncha), 5 *Rhadinorhynchus pristis* (Acanthocephala: Rhadinorhynchidae), and 385 hemiurids of the genus *Lecithochirium* (Digenea: Hemiuridae) were recovered. The hemiurids were represented by 3 species. The most abundant was *Lecithochirium musculus* with 315 individuals, followed by *Lecithochirium fusiforme* with 52 specimens, and 18 *Lecithochirium furcolabiatum*. Mixed infections with *L. musculus* and *L. fusiforme* occurred in only 3 fish. The remaining 61 fish were infected with only 1 of the hemiurid species. Some hemiurids were badly preserved and could not be accurately identified (n = 8). Mean intensity of hemiurids was 7.9 for *L. musculus* and 4.7 for *L. fusiforme*. *Lecithochirium furcolabiatum* was the least common digenean. Prevalence, mean intensity, and mean abundance values of the helminth species found are shown in Table I. The highest prevalence, 62.5% (95% confidence limits 49.5–74.3%), was observed for *L. musculus*, followed by *S. tergestinus* (26.6%, 95% confidence limits 16.3–39.1%), and *L. fusiforme* (17.2%, 95% confidence limits 8.9–28.7%). Estimates of the aggregation indices, variance-to-mean ratios (s^2/x), and index of discrepancy (D) for *L. musculus* and *L. fusiforme* indicated that their frequency distributions are overdispersed ($\chi^2 = 24.35$, $P = 0.05$, $s^2/x = 14.0$, $D = 0.672$ for *L. musculus*; $\chi^2 = 2.49$, $P = 0.05$, $s^2/x = 8.1$, $D = 0.90$ for *L. fusiforme*). For *S. tergestinus*, however, s^2/x was 4.2 and $D = 0.827$; its distribution was aggregated ($\chi^2 = 10.2$; $P = 0.05$).

An analysis of the vertical distribution of *L. musculus* and *L. fusiforme*, the 2 most abundant hemiurid parasites, with depth of capture, indicated that intensity of *L. musculus* decreased significantly with depth ($r = -0.391$; $P = 0.01$ [n = 61]), whereas the intensity of *L. fusiforme* increased significantly with depth ($r = 0.292$; $P = 0.05$ [n = 61]; see Fig. 1). *Lecithochirium musculus* is more abundant at depths of 200–300 m, whereas *L. fusiforme* is more abundant at depths of 400–600 m. Postlarvae of *S. tergestinus* increased significantly with depth ($r = 0.329$, $P = 0.01$ [n = 61]), being more frequent at depths of 400–700 m (Fig. 1). The relationship between host length and abundance of *L. musculus* and *S. tergestinus* was positive, but not significant ($r_s = 0.049$; $P = 0.71$; $r_s = 0.074$; $P = 0.57$). Relationship between host length and abundance of *L. fusiforme* was negative, but not significant ($r_s = -0.091$; $P = 0.48$).

Differences were found between the helminth fauna of conger eels in Madeira and in the Iberian Atlantic coast. One of these differences relates to the occurrence of postlarvae of the trypanorhynch *S. tergestinus*. This cestode, with a relatively high prevalence of 26.6%, was not previously reported from conger eels. Rather, the trypanorhynch *Grillotia* sp. was reported from conger eels along the Iberian Atlantic coast (SanMartin et al., 2000) and elsewhere (Palm, 2004). Postlarvae of *S. tergestinus* were more abundant in deeper waters (see Fig. 1), where it is possible that the diet of conger eels included more crustaceans, which could include intermediate hosts of this cestode. Oceanic trypanorhynchids are known to have a life cycle with crustaceans or fish as second intermediate hosts (Palm, 2004). Moreover, Sphyriocephalidae are common in deeper waters (Klimpel et al., 2001, quoted by Palm, 2004).

In contrast to surveys conducted in the Iberian Atlantic coast, we found a very low prevalence of the nematode *Cristitectus congeri* (1 specimen only in 61 fish). This parasite, a specialist nematode of conger eels (Petter, 1970; Quinteiro et al., 1989), is present along the Iberian coast, with prevalences ranging from 8.2% (n = 110) in northwestern Spain (Quinteiro et al., 1989) to 54.8% (in northwestern Spain, at the mouth of Ria de Arousa; Quinteiro et al., 1992), and to 50%, as reported by Saraiva et al. (2000) from the Atlantic Portuguese coast (in northwestern Portugal). Another nematode recovered from conger eels in our study with a low prevalence included L3 larval stages of *Anisakis simplex* s.l. This low

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TABLE I. Prevalence, mean intensity, and abundance of the helminth parasites found in the stomach of conger eel, *Conger conger*, from Madeiran waters.

Parasite species	Prevalence (%)	No. infected fish	No. parasites	Mean intensity (range)	Abundance
Cristitectus congeri	0.02	1	1	1	0.02
Anisakis simplex s.l.	6.3	4	5	1.25 (1–2)	0.08
Sphyriocephalus tergestinus	26.6	17	48	2.82 (1–8)	0.75
Rhadinorhynchus pristis	0.02	1	5	5	0.08
Lecithochirium musculus	62.5	40	315	7.88 (1–53)	4.92
Lecithochirium fusiforme	17.2	11	52	4.73 (1–13)	0.81
Lecithochirium furcolabiatum	6.3	4	18	4.50 (1–9)	0.28

prevalence was probably because they are usually more abundant in the body cavity of fishes. Low prevalence of *A. simplex* was also reported in conger eels from the Iberian Peninsula (9.0%) by SanMartin et al. (1989), and 1.1% by SanMartin et al. (2000). In contrast, Saraiva et al. (2000) registered very high prevalence (94%) in the mesenteries of conger eels.

Variations in prevalence of the helminth parasites observed in the present study and elsewhere may reflect variability in habitats occupied by fishes and the availability of intermediate hosts. The regions sampled in the Iberian Atlantic coast represented continental coastal waters, whereas Madeira is an oceanic island, with almost no continental shelf, which could account for further differences in prevalence due to nutrient-poor waters, which support low numbers of invertebrate intermediate hosts. For example, transmission of cystidicolid nematodes to fish takes place via the ingestion of crustaceans (amphipods and decapods) (Anderson, 1992). Amphipods were not identified in the diet of conger eels from Madeira, whereas decapods represented a high percentage of the diet, e.g., Natantia (56.9%) and Brachyura (1.2%; L. Costa, unpubl. obs.). Whether the Natantia or the Brachyura are intermediate hosts for *C. congeri* is not known at this point. Nonetheless, crustaceans and fishes were the most abundant food items (56.9% and 17.2%, respectively) with Mollusca (including cephalopods) accounting for 3.0% of the diet in conger eels in Madeira.

The hemiurid trematodes represented the most abundant of the helminth parasites in our study, but they are also common parasites of conger eels in the Mediterranean (Bartoli and Gibson, 2007) and less common in the Iberian Atlantic coast (Vilas et al., 2003), implicating the existence of a link with the Mediterranean in terms of these digenean parasites. Typically, *Lecithochirium* species are acquired by feeding on small rock-pool fishes (see Gibson and Bray, 1986), namely, gobies and labrids, which are common in Madeiran rocky shores (Wirtz, 1994). However, it was of interest to find that *L. musculus* was more abundant in fish caught at depths of 200–300 m, whereas *L. fusiforme* was at depths 400–600 m (see Fig. 1). This could be related to changes in the prey items of conger eels. According to Cau and Manconi (1984), the most frequent

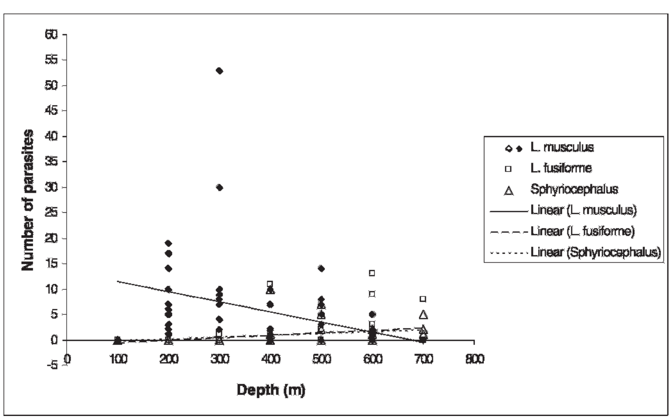

FIGURE 1. Number of individual *Lecithochirium musculus* and *Lecithochirium fusiforme*, and postlarvae of the trypanorhynchan *Sphyriocephalus tergestinus* in conger eels, *Conger conger* in relation to depth of capture, from Madeiran waters.

prey in neritic populations of conger eels is fishes (suitable for transmission of hemiurids), with crustaceans and molluscs as chance prey. On the other hand, in the mesobathyal region, fish and crustaceans (suitable for transmission of hemiurid trematodes, trypanorhynchs, and nematodes) are the preferential prey, thus explaining the presence of *S. tergestinus* in deeper waters.

The occurrence of the acanthocephalan *R. pristis*, not previously registered from conger eels, seems likely to be an accidental infection. This acanthocephalan is fairly common in Madeiran waters, infecting the intestine of fishes (Costa et al., 2004).

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